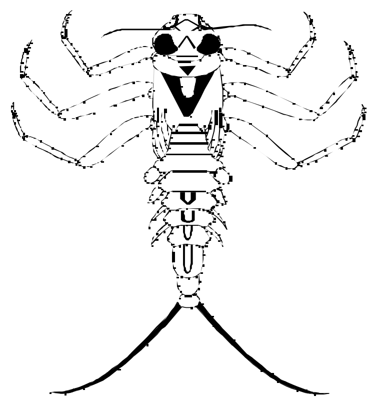
Bio-monitoring of Water Quality Using Aquatic Invertebrates and In-stream Habitat and Riparian Condition Assessment: Status Report for Pipestone Creek, Pipestone National Monument, Minnesota 1989-2004



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1.0 INTRODUCTION

The National Park Service (NPS) began monitoring the aquatic invertebrates of Pipestone Creek within Pipestone National Monument, Minnesota in 1989, with that year's data serving as a baseline (Harris et al. 1991). Sporadic sampling between 1992 and 1995 was done through funding provided by the Midwest Regional Office of NPS. However, most of the sampling was conducted outside the season of interest for this report, summer. Concerted monitoring efforts began again in 1996, following creation of the Prairie Cluster Prototype Long-term Ecological Monitoring Program, now known as the Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program – a base-funded science program to monitor natural resources at Pipestone National Monument and sixteen other Midwestern NPS units. In-stream habitat and riparian condition assessments were conducted in 2002 and 2003 to monitor the quality of habitat available and other factors influencing aquatic invertebrate communities within Pipestone Creek. The purpose of this report is to summarize aquatic invertebrate monitoring data collected in 1996 through 2004 and to assess changes in community structure through time, especially since the 1989 baseline year. In-stream habitat and riparian assessment results are reported as well.

Benthic invertebrates are the most common group of organisms used to assess water quality (Rosenberg and Resh 1993). They are attractive as indicators because they represent a diverse group of long-lived, sedentary species that react strongly and often predictably to human influences on aquatic systems (Cairns and Pratt 1993). The objectives of this bio-monitoring program are to determine the annual status of stream invertebrate communities in order to assess the water quality of Pipestone Creek and to detect changes through time in aquatic invertebrate communities. The in-stream habitat and riparian condition assessments will give us a better understanding of the environment in which the aquatic communities have evolved.

1.1 Background

Pipestone Creek, a tributary of the Big Sioux River, meanders from east to west about 100 km through southwestern Minnesota – southeastern South Dakota. The creek originates 19.3 km northeast of Pipestone National Monument as a drainage ditch near Holland, Minnesota (Harris et al. 1991). The creek merges with Split Rock Creek near Jasper, Minnesota before entering the Big Sioux River approximately 80.0 km southwest of the park near Corson, South Dakota. The city of Pipestone, Minnesota lies on the south side of the creek and borders the park on the south end. Pipestone Creek flows through the center of the park and widens twice within its boundaries to form Lake Hiawatha and an unnamed pond. A recreational lake on Pipestone Creek borders the Monument on the west side.

Natural vegetation of the area is bluestem prairie (Kuchler 1964, Stubbendieck and Willson 1986). However, agricultural row cropping is the primary land use in the watershed. The area is part of Omernick's (1987) Northern Glaciated ecoregion, with a Precambrian era bedrock of Sioux Quartzite. Pipestone, a thin layer of sedimentary rock underlying the Sioux Quartzite, has been mined in the region for over 400 years. Active quarries are still found within Pipestone National Monument. A natural waterfall within the park was lowered 2.5 to 3.0 m in the early 1900's resulting in increased sedimentation of the waterway downstream (Harris et al. 1991).

Pollution History.**--**Water pollution within the watershed is primarily of agriculture in nature. The city of Pipestone, Minnesota releases effluent into Pipestone Creek below the park boundary. Water Resources Division, National Park Service, conducted an extensive review of historic water quality data for an area four point eight kilometers upstream and one point six kilometers downstream of the park (Water Resources Division 1999). Water Resource Division identified periods since 1974 when dissolved oxygen, pH, cadmium, copper, lead, and zinc have exceeded their respective EPA criteria for the protection of freshwater aquatic life. Concentrations of nitrate, nitrite plus nitrate, chloride, cadmium, lead and methylene chloride have exceeded EPA drinking water criteria during monitoring events since 1974. Fecal-indicator bacteria concentrations and turbidity have also exceeded Water Resource Division screening limits for freshwater bathing and aquatic life, respectively. Currently, Pipestone Creek is listed by the state of Minnesota as a 303d waterway due to fecal coliform contamination (Minnesota Pollution Control Agency 2004). Monitoring efforts prior to 1974 were not identified in the Water Resource Division report (1999) or for this report.

2.0 METHODS

2.1 Aquatic Invertebrate Sampling

The details of field and laboratory procedures are described in Peterson et al. (1999), and summarized below.

Monitoring Sites.--Harris et al. (1991) established two monitoring sites within the park, along Pipestone Creek (Figure 1). Five replicate Surber samples were collected at each site during each sampling event.

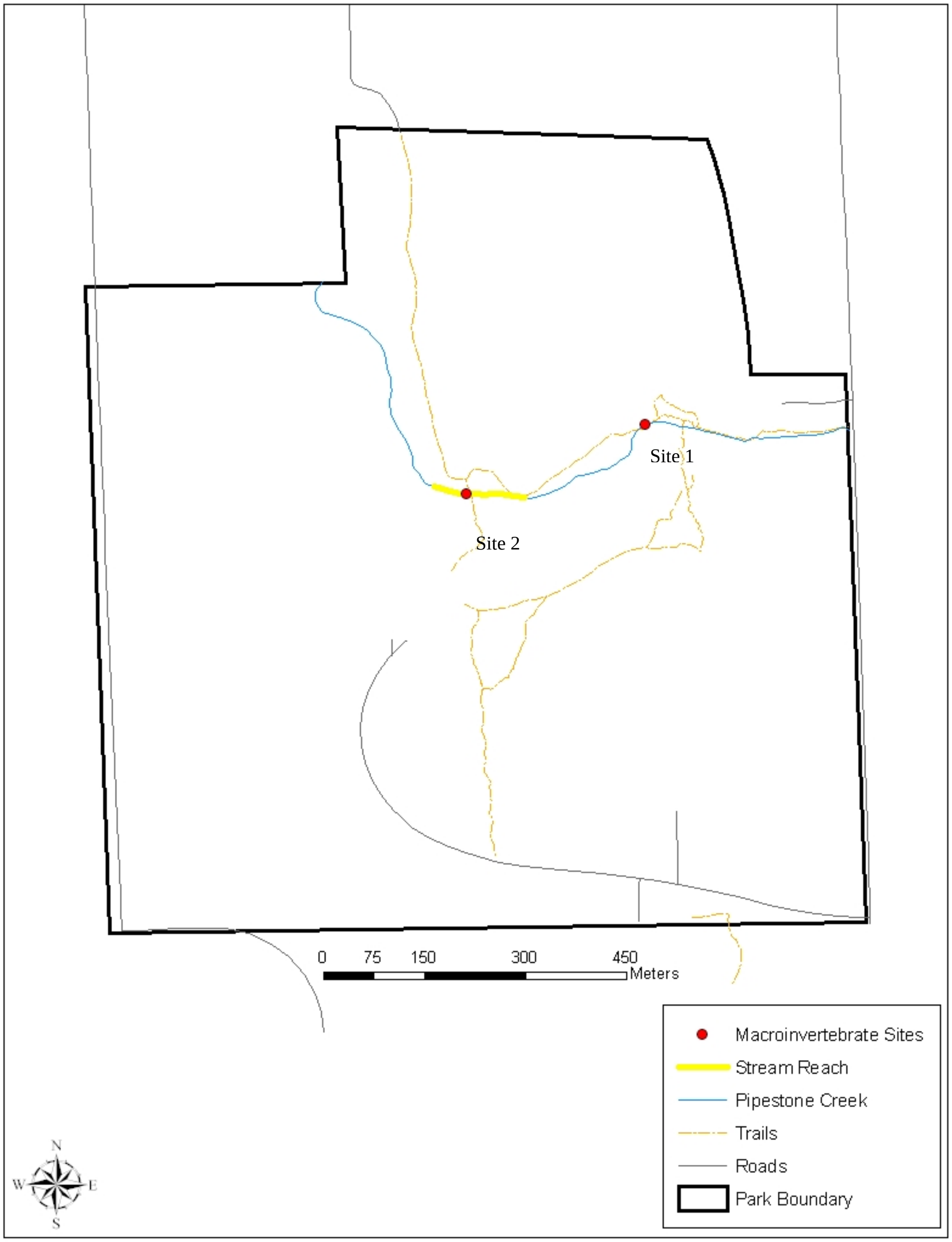

Figure 1. Aquatic invertebrate and in-stream habitat and riparian condition assessment sites on Pipestone Creek at Pipestone National Monument, Minnesota.

Sampling Frequency And Timing.--The monitoring protocol calls for the collection of five replicate samples from each of two sites at approximate monthly intervals during a summer sampling window defined by growing degree days (i.e. days with average daily temperature above 10°C). For Pipestone National Monument, normal average daily temperatures fall within this range for the period 18 June through 18 September (National Weather Service). The samples included in this report were collected between 20 June and 23 September.

Field Sampling.--Benthic invertebrate samples were collected from shallow riffle areas of the stream with a Surber sampler following methods outlined by Peterson et al. (1999). To minimize disturbance of a site prior to sampling, samples were collected from the most downstream riffle at a site first, then progressing upstream until five samples were collected for that site. A small rake was used to dislodge organisms from the substrate inside the sampler. Cobble inside the sampler was scrubbed with a vegetable brush to dislodge additional organisms. Invertebrates were carefully removed from the sampler and placed in labeled jars containing 80 % ethyl alcohol. Samples were then prepared for shipping and sent to a lab for species identification and enumeration.

Colorado State University investigators collected aquatic invertebrate samples in 1989 (Harris et al. 1991). Park staff and cooperators collected aquatic invertebrate samples for the period 1996-2004.

Aquatic invertebrates were identified and enumerated by Dr. Boris Kondratieff's lab, Colorado State University for the period 1989 (Harris et al. 1991); and by Dr. Charles Rabeni's lab, Missouri Cooperative Fish and Wildlife Research Unit, University of Missouri-Columbia for 1996-2004. Invertebrates were identified to the lowest taxonomic level possible, which was generally to genus.

To insure the consistency of data collected in the future, NPS personnel at Pipestone National Monument will continue to collect five replicate aquatic invertebrate samples from each of two sites, three times annually. Additional physical and chemical parameters will be measured each time an aquatic invertebrate sample is collected and incorporated into future water quality analysis.

Community Indices.--The monitoring protocol recommended using a suite of four community indices to describe changes in community structure (Table 1; Peterson et al. 1999). Peterson (1996) identified four metrics to be the least redundant and most indicative of water quality from a list of nine metrics using Pearson correlation comparisons and a Principal Components Analysis of the correlation matrix. Additionally, we include Taxa Richness and EPT Richness in this report for the purposes of comparison with aquatic invertebrate monitoring data from other sources.

Table 1. Metrics used to characterize the aquatic invertebrate communities of Pipestone Creek, Pipestone National Monument, Minnesota and chosen as indicative of changing water quality through time. An asterisk indicates metrics originally selected by Peterson (1996).

Metric(Reference)	Definition	Expected Response
EPT Richness (Resh and Grodhaus 1983)	Number of Ephemeroptera, Plecoptera, and Trichoptera taxa present per sample.	Lower richness indicates that a stream may have been subjected to one or more pollution stresses. In general, the majority of taxa in these three orders are pollution sensitive.
EPT Ratio* (Resh and Grodhaus 1983)	EPT/(EPT + Chironomidae) The number of EPT individuals in a sample divided by this sum plus the number of Chironomidae.	Lower EPT Ratio indicates that a stream may have been subjected to one or more pollution stresses. A stressed habitat reflects an imbalance between pollution-tolerant Chironomidae and pollution-sensitive EPT taxa.
Family Diversity* (Shannon-Wiener Index: Shannon and Weaver 1949)	$H' = -\Sigma(n_i / N)*\ln(n_i / N)$ N is the total number of individuals in a sample and n_i is the total number of individuals in the *i*th family.	Lower diversity indicates that a stream may have been subjected to one or more stresses.
Family Richness* (Resh and Grodhaus 1983)	Number of families present per sample.	Lower richness indicates that a stream may have been subjected to one or more stresses.
Family Biotic Index* (Hilsenhoff 1988)	$FBI = \Sigma n_i a_i / N$ N is the total number of individuals in a sample, n_i is the total number of individuals in a family, and a_i the tolerance value for the *i*th family.	Higher FBI indicates that a stream may have been subjected to one or more stresses. This index weights the relative abundance of each family by its relative pollution tolerance value to determining a community score. Therefore, pollution-tolerant species are weighted heavier than pollution-sensitive species in the index.
Taxa Richness (Resh and Grodhaus 1983)	Number of all taxa present per sample.	Lower richness indicates that a stream may have been subjected to one or more stresses.

2.2 In-stream Habitat and Riparian Condition Assessment

Details on procedures for assessing in-stream habitat and riparian condition are described in Peitz (draft), and summarized here. Eleven transects spaced equal distances apart along a 150-m reach were used to assess in-stream habitat and riparian condition. The first two transects were located downstream of the aquatic invertebrate sample site. The third transect was located at the sample site with the remaining eight upstream at 15-m intervals. Water quality measurements, dissolved oxygen, conductivity, pH, temperature and water clarity were taken at a representative location along the reach before entry into the stream to complete other assessment work. This kept observers from impacting water quality results. Dissolved oxygen (DO) and temperature were measured using an YSI 55 meter. Conductivity, relative conductivity and pH were measured using an YSI 63 meter. Water clarity or cloudiness caused by suspended or dissolved materials in the water was measured using a 120 cm Secchi tube.

In-stream discharge, flow stage, fluctuation rating and channel morphology were assessed and recorded for the stream reach at the completion of all in-stream habitat and riparian condition assessments. The presence and type of channel alterations as well as sedimentation and excessive algae problems was noted. Also noted was the amount and date of all recent rains if any. Pools located within the reach were recorded as belonging to one of four classes depending on depth: class 1, pool > 3 ft; class 2, pool > 2 ft; class 3, pool >1 ft; and class 4, pool is shallow and pool/riffle/run/bend ratio determined. Channel sinuosity and a stream degradation rating were determined for the reach.

In-stream habitat and riparian condition parameter were assessed at each transect and results recorded in one of three categories; in-stream, stream bank or riparian zone. Stream bank and riparian zones were assessed on the left and right side of the stream separately. Right and left banks were determined when looking downstream. Both in-stream habitat and stream bank assessments were done for an area 5-m either side of each transect. Stream bank was the area between the wetted edge of the stream and point of bank full (the point were the stream would leave its banks at flood stage). The riparian zone was assessed for an area 10 m^2 centered on each transect and starting at the bank full mark of the stream. Coverage of vegetation, woody debris and other structures were determined for in-stream, stream bank and riparian areas. Substrate type and embeddedness were determined and recorded for both in-stream and stream bank area's. The occurrence of filamentous algae, floating vegetation, rooted vascular plants and large woody debris were recorded. Upper and lower bank stability, severity of grazing damage if any and overall assessment of buffer zone condition was also made for each side of a transect. The depth of the Thalweg and substrate present at the point of the Thalweg were recorded during the 2003 survey.

2.3 Statistical Analysis Methods.

Aquatic Invertebrate Analysis.--The invertebrate indices for Pipestone Creek were compared graphically using means and an estimate of variance. This analytical approach was chosen over other statistical analysis options because of an imbalance among years in the number of samples collected. Specifically, in 1988 and 1996 when samples were collected on only one date. During 1997–2004 samples were collected on three different dates within each year, exception being 2003 when only two samples were collected. Also, within some years June samples tended to be more variable than July, August or September samples (Appendix A). On each date, two sites were sampled with five replicates at each site. The exception being 13 July 1998 when only four replicates were collected at site one.

Annual means and standard errors for Pipestone Creek were calculated from means for each sample site and date. These means and standard errors were graphed and used to make annual water quality comparisons for Pipestone Creek within the monument. As more data is collected, annual variations and trends in the water quality of Pipestone Creek will be investigated using more rigorous statistical methods. Both, the correlation of data collected at the same site through time and the lack of independence of samples collected at a site on any given date will be considered in future analysis.

In-stream Habitat and Riparian Condition Assessment Analysis.--Annual means were calculated for parameters measured within the stream reach. Using these means an overall mean and standard error for each parameter was calculated. Mean parameter values give us a baseline from which we can assess the influences of the physical and chemical environment on the aquatic invertebrate communities within Pipestone Creek. As more data is collected, the relationship between in-stream habitat and riparian conditions with invertebrate communities in Pipestone Creek will be investigated using more rigorous correlation analysis.

3.0 RESULTS

Aquatic Invertebrates.--The annual aquatic invertebrate indices for Pipestone Creek at Pipestone National Monument, Minnesota are reported on Table 2 and displayed in Figure 2. The raw data are reported by sampling event and site in Appendix A as well.

Table 2. Mean (+ SE) metric values for the aquatic invertebrate communities in Pipestone Creek at Pipestone National Monument, Minnesota from 1989 to 2004.

	Mean (SE)									
Aquatic Invertebrate Index	1989 n = 2	1996 n = 2	1997 n = 6	1998 n = 6	1999 n = 6	2000 n = 6	2001 n = 6	2002 n = 6	2003 n = 6	2004 n = 4
EPT Richness	3.10	3.20	2.67	1.23	6.20	4.53	4.20	5.70	4.23	5.45
	(0.1)	(0.00)	(1.23)	(0.20)	(0.38)	(0.47)	(0.21)	(0.51)	(0.42)	(1.07)
EPT Ratio	0.63	0.62	0.36	0.53	0.32	0.23	0.40	0.40	0.77	0.65
	(0.05)	(0.13)	(0.06)	(0.11)	(0.05)	(0.06)	(0.03)	(0.05)	(0.09)	(0.05)
Family Diversity	1.66	1.44	0.94	0.90	1.16	1.09	1.19	1.30	1.24	1.28
	(0.03)	(0.27)	(0.17)	(0.10)	(0.14)	(0.16)	(0.13)	(0.10)	(0.15)	(0.12)
Family Richness	8.80	6.60	5.27	3.33	9.43	9.33	6.87	8.40	6.83	6.60
	(0.00)	(2.20)	(1.57)	(0.27)	(0.96)	(1.02)	(0.74)	(0.88)	(1.00)	(0.73)
Family Biotic Index	5.32	4.85	5.12	4.67	5.34	5.59	5.38	5.17	4.43	4.65
	(0.14)	(0.14)	(0.21)	(0.33)	(0.12)	(0.11)	(0.10)	(0.07)	(0.32)	(0.13)
Taxa Richness	12.5	9.20	8.33	4.22	15.03	14.00	10.73	13.87	9.60	11.40
	(0.30)	(3.00)	(2.45)	(0.53)	(1.00)	(1.49)	(1.09)	(0.94)	(1.20)	(1.19)

Richness, the number of taxa at a given taxonomic level, indicates that water quality of Pipestone Creek improved significantly in 1999 and has remained stable or declined only slightly since than (Table 2 and Fig. 2). EPT taxa richness (Fig. 2a) and family level richness (Fig. 2d) have remained constant since 1999 based on comparisons of means and standard errors. Total taxa richness values have fluctuated annually since 1999 with the overall trend in water quality based this metric stable to declining slightly. All three levels of richness have annually approached, equaled or exceeded the baseline levels of 1989. Based on means and standard errors, EPT richness (the richness of pollution intolerant Ephemeroptera, Plecoptera and Trichoptera taxa) has improved the most with time.

EPT ratio (Fig 2b), Family Diversity (Fig. 2c) and Family Biotic Index (Fig. 2e) values indicate that the water quality of Pipestone Creek is stable to improving through time. The EPT ratio, a measure of the number of individuals in the EPT taxa to the number of pollution tolerant Chironomids, had declined significantly through 2000 but has been improving ever since. Family diversity declined in 1997 and 1998, however, this metric has improved or remained constant each year since. Family biotic index values remained constant from 1989 through 2002 with improvements (declines) in this metric seen in 2003 and 2004.

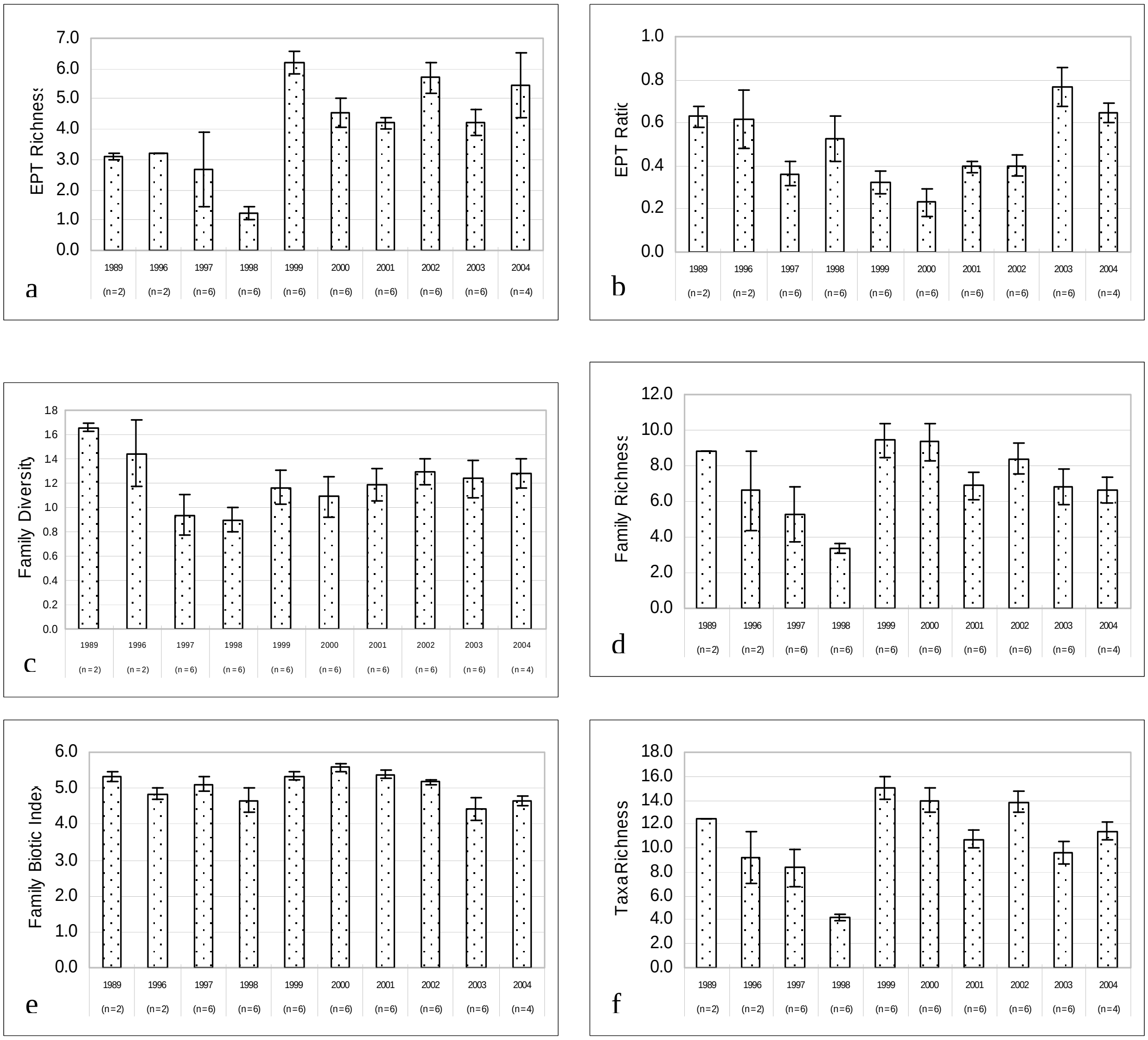

Figure 2. Mean (± SE) metric values for the aquatic invertebrate communities in Pipestone Creek at Pipestone National Monument, Minnesota from 1989 to 2004.

In-stream Habitat and Riparian Condition Assessments.--Average habitat conditions for Pipestone Creek at Pipestone National Monument, Minnesota during 2002-2003 are shown in Table 3. Flow in the creek was determined to be moderate to high with a recent rain event of 1.63 cm recorded during our 2002 assessments. The fluctuation rating for the creek was determined to be moderate to severe. Sinuosity of Pipestone Creek is low to moderate. Excessive sedimentation and algae growth were not noted within the assessment reach. Flow within the assessment reach has been altered somewhat to accommodate a walk bridge. Flow was also altered in 2002 by a beaver dam located in the reach. Riffles and runs are common throughout the reach. Therefore, the pool/riffle/run/bend ratio was low, less than 5-7, which is good. Class 1 pools occurred occasionally in the reach in 2002 and class 2 pools were common. Class 1 and 2 pools occurred occasionally in the reach in 2003 and class 3 and 4 pools were common. Stream degradation was minor to moderate within the reach assessed. The condition of the buffer zone along the reach was poor to good, mostly good and grazing damage almost nonexistent. Moderate grazing damage by beaver occurred in one small area along the reach.

Table 3. Mean (± SE) values for habitat parameters measured in Pipestone Creek at Pipestone National Monument, Minnesota in 2002 and 2003.

	Mean	Std. Err	Minimum	Maximum	Range
	Water chemistry parameter				
Water temperature (C^o)	16.90	0.20	16.70	17.10	0.40
Dissolved oxygen (mg/l)	7.75	0.48	7.27	8.23	0.96
Conductivity (uS/cm)	565.00	29.00	536.00	594.00	58.00
pH	8.08	0.06	8.02	8.13	0.11
Water clarity (cm)	39.30	1.70	37.60	41.00	3.40
	In-stream habitat parameter				
Stream width (m)	5.98	0.15	2.50	9.40	6.90
Thalweg depth (m)—2003 only	0.84	--	0.27	1.65	1.38
Canopy cover (%)	16.62	0.43	16.19	17.04	0.85
In-stream vegetation cover (%)	11.25	3.61	1.00	62.50	61.50
Small woody debris cover (%)	5.20	3.07	0.00	15.00	15.00
Overhanging vegetation cover (%)	34.27	15.05	3.50	62.50	59.00
Undercut bank (%)	7.23	3.50	0.00	62.50	62.50
Boulder cover (%)	45.66	18.20	1.00	85.00	84.00
Artificial structure cover (%)	0.84	0.84	0.00	15.00	15.00
	Stream bank parameter				
Height (m)	0.63	0.08	0.11	1.40	1.29
Slope (^{o})	15.15	0.22	0.00	38.00	38.00
Grass/forb cover (%)	73.92	9.49	15.00	97.50	82.50
Shrub/vine cover (%)	2.84	2.18	0.00	62.50	62.50
Understory trees cover (%)	0.67	0.38	0.00	15.00	15.00
Overstory tree cover (%)	4.19	1.81	0.00	62.50	62.50
Bare soil cover (%)	12.20	6.68	0.00	37.50	37.50
Bare rock cover (%)	16.16	3.11	0.00	62.50	62.50
Woody debris cover (%)	0.91	0.16	0.00	15.00	15.00
	Riparian parameter				
Grass/forb cover (%)	56.02	4.16	1.00	97.50	96.50
Shrub/vine cover (%)	23.09	6.77	0.00	85.00	85.00
Tree seedling cover (%)	1.42	0.24	0.00	15.00	15.00
Understory tree cover (%)	6.58	1.24	0.00	37.50	37.50
Overstory tree cover (%)	22.40	1.81	0.00	85.00	85.00

Average water quality measurements taken at a representative location along the assessment reach are given in Table 3. These measurements may have been influenced by runoff from recent rain events and/or return flow in 2002. However, water quality was not influenced by recent rain or return flow in 2003. Stream discharge within the reach averaged 0.14 m^3/s and average stream depth at the point of discharge was 0.15 m. Average Thalweg depth for the total reach was 0.84 m. Cobble made up 41% of the substrate within the reach followed by boulders (33%), sand (19%), gravel (4%) and bedrock (3%). The presence of large substrate materials, those much greater than 64.0 mm in diameter, limited 50% of substrate embeddedness to less than 25%. However, 30% of the substrate materials present in Pipestone Creek were embedded greater than 75%, most of which was near the creek's bank. Nine percent of the in-stream substrate material was embedded 25-50% and 5% was embedded 50-75%. Six percent of our measurements fell on bedrock which has no embeddedness. Figure 3 illustrates the average depth and flow at ¼, ½ and ¾ of the distance across the river.

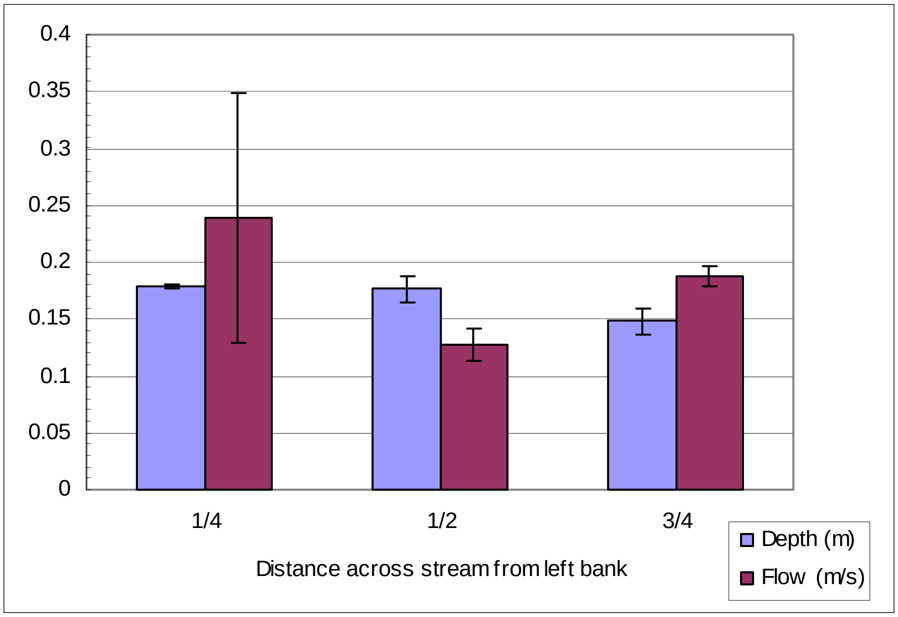

Figure 3.0. Mean (+ SE) stream depth and flow at ¼, ½ and ¾ of the way across Pipestone Creek from left bank. Measurements were taken within Pipestone National Monument, Minnesota in 2002 and 2003.

Average cover of vegetation, brush and small woody debris, overhanging vegetation, undercut banks, boulders and artificial structures in Pipestone Creek within our assessment reach are given in Table 3. Within the reach canopy cover average approximately 17% across years. In stream large woody debris was absent from the assessment reach. Rooted vascular plants were recorded as nonexistent to common along the assessment reach depending on which transect one was at. However, rooted vascular plants occurred occasionally along most of the reach. Filamentous algae occurred occasionally to commonly along the assessment reach.

Almost 98% of the stream bank stability was rated as being in good condition. The dominant stream bank substrate was silt (50%) and boulders (34%) and vegetation cover grass/forbs (74%; Table 3). The riparian area along the stream bank was dominated by upland-prairie (50 %) and a mix of other habitat types.

4.0 DISCUSSION

In summary, it appears that the water quality of Pipestone Creek within Pipestone National Monument, while fluctuating slightly has remained stable since a significant improvement was noted in 1999. When looking at results of our monitoring efforts it is important to keep in mind that our data for Pipestone Creek has not been compared to reference streams in the region, and the observed changes are only relative to conditions observed previously. Pipestone Creek is listed as a 303d impaired waterway by the state of Minnesota (Minnesota Pollution Control Agency 2004). This listing of Pipestone Creek as a 303d waterway is based on fecal coliform concentrations exceeding levels for aquatic consumption/aquatic recreation and not on other contaminants such as chemicals from agricultural runoff or sedimentation, that might depress aquatic invertebrate communities differently. Row crop agriculture and runoff from impervious surfaces within the City of Pipestone are two of the main threats to the quality of water in Pipestone Creek.

An expansion of the water quality monitoring within the Monument included chemical and physical measures in 2002-2003. This has allowed us the opportunity to establish a baseline on which to measure changes in in-stream habitat conditions in the future. The effects these changes have on the invertebrate communities, our biological measure of water quality in Pipestone Creek, can now be assessed better. Changes in the aquatic invertebrate communities are often related to changes in in-stream substrate composition and structure (invertebrate habitat), which are influenced by runoff from areas upstream. Changes in agricultural practices and what is allowed to enter Pipestone Creek from city runoff will affect aquatic invertebrate communities and the quality of water they represent. We are scheduled to reassess in-stream habitat and riparian conditions in 2007-2008.

5.0 MANAGEMENT IMPLICATIONS

The generally stable conditions of Pipestone Creek within Pipestone National Monument, Minnesota suggest little to no active management would be needed, if stable water quality or in-stream habitat and riparian zone conditions are desired. However, Monument staff could help improve water quality by working with land owners and city officials upstream on ways to expand riparian buffer zones to control what runoff enters Pipestone Creek. City officials could also implement or expand efforts to sweep streets to reduce the amount of material allowed to enter the creek. The long history and continuing efforts with water quality monitoring in Pipestone Creek provides a sound tool to recognize both a rapid deterioration of water quality as well as a chronic decline.

6.0 ACKNOWLEDGEMENTS

We would like to thank all of those who have contributed to aquatic invertebrate monitoring at Pipestone National Monument, Minnesota over the years. In particular, we would like to thank Kristin Legg and Gia Wagner, Natural Resource Managers and the numerous seasonal employees who assisted with invertebrate sample collection. We would also like to thank personnel with the Minnesota Youth Conservation Corp who have assisted with sampling.

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Appendix A. Mean (± Std Dev) values for the aquatic invertebrate metrics calculated for Pipestone Creek, Pipestone National Monument, Minnesota by sample date and sample site.

Date	n	Taxa Richness	Family Richness	Family Diversity	EPT Richness	EPT Ratio	FBI
			Pipestone Creek Site 1				
06/22/89	5	12.80 (0.66)	8.80 (0.86)	1.69 (0.11)	3.20 (0.20)	0.68 (0.04)	5.46 (0.07)
08/07/96	5	6.20 (0.80)	4.40 (0.75)	1.18 (0.19)	3.20 (0.73)	0.75 (0.08)	4.99 (0.41)
06/26/97	5	19.60 (2.82)	12.20 (1.71)	1.23 (0.21)	8.40 (0.87)	0.25 (0.08)	5.69 (0.19)
08/13/97	5	3.40 (1.36)	2.40 (0.93)	0.54 (0.29)	1.40 (0.68)	0.60 (0.19)	5.18 (0.55)
09/23/97	5	3.80 (0.8)	2.00 (0.45)	0.47 (0.20)	0.80 (0.37)	0.24 (0.13)	5.62 (0.23)
07/13/98	4	5.50 (0.96)	3.75 (1.03)	1.12 (0.38)	1.00 (0.58)	0.29 (0.17)	6.20 (0.51)
08/19/98	5	2.20 (0.97)	2.20 (0.97)	0.47 (0.32)	0.80 (0.58)	0.28 (0.18)	4.68 (1.38)
09/13/98	5	4.40 (1.03)	3.20 (0.49)	1.02 (0.18)	2.00 (0.32)	0.88 (0.08)	4.22 (0.26)
07/13/99	5	16.20 (1.88)	9.20 (0.86)	1.11 (0.13)	7.00 (0.45)	0.29 (0.07)	5.42 (0.12)
08/16/99	5	12.80 (1.28)	7.80 (1.02)	1.07 (0.10)	5.80 (0.49)	0.39 (0.07)	5.18 (0.16)
09/15/99	5	12.00 (0.95)	7.40 (0.81)	1.04 (0.11)	5.40 (0.68)	0.44 (0.13)	5.11 (0.25)
06/20/00	5	16.00 (1.79)	7.60 (1.03)	0.70 (0.12)	5.00 (0.71)	0.12 (0.04)	5.84 (0.09)
07/21/00	5	11.60 (2.79)	8.00 (1.64)	1.01 (0.34)	4.00 (1.45)	0.24 (0.10)	5.59 (0.15)
08/22/00	5	7.80 (0.20)	6.00 (0.32)	0.78 (0.11)	2.60 (0.24)	0.18 (0.05)	5.59 (0.12)
07/18/01	5	9.00 (2.07)	5.60 (0.75)	0.97 (0.16)	3.80 (0.86)	0.37 (0.11)	5.34 (0.19)
08/23/01	5	10.60 (1.29)	5.80 (0.73)	1.08 (0.06)	4.20 (0.73)	0.42 (0.04)	5.49 (0.22)
09/12/01	5	6.60 (1.66)	4.40 (1.03)	0.82 (0.22)	4.00 (0.84)	0.50 (0.18)	5.06 (0.36)
7/10/02	5	15.60 (3.91)	8.60 (2.07)	1.14 (0.36)	6.60 (1.52)	0.31 (0.20)	5.47 (0.42)
8/13/02	5	13.20 (1.10)	6.60 (0.89)	1.14 (0.20)	7.20 (0.45)	0.50 (0.16)	5.16 (0.29)
9/18/02	5	9.80 (3.11)	5.00 (1.73)	0.97 (0.19)	5.00 (1.58)	0.55 (0.28)	5.00 (0.62)
7/09/03	5	8.60 (2.70)	5.80 (2.05)	1.37 (0.41)	3.40 (2.07)	0.42 (0.28)	5.82 (0.18)
8/11/03	5	7.60 (3.05)	4.20 (1.64)	0.76 (0.34)	3.80 (1.48)	0.89 (0.10)	4.21 (0.13)
9/08/03	5	8.80 (2.49)	5.00 (1.22)	0.88 (0.32)	5.00 (1.22)	0.89 (0.06)	4.20 (0.10)
7/19/04	5	8.00 (1.87)	5.20 (1.10)	1.15 (0.20)	3.60 (1.14)	0.69 (0.17)	4.86 (0.45)
8/25/04	5	12.60 (3.36)	6.00 (1.22)	1.05 (0.29)	7.20 (1.10)	0.76 (0.13)	4.56 (0.30)
			Pipestone Creek Site 1 – kick-net sample				
9/18/02	1	16	9	0.97	8	0.78	4.57
9/08/03	1	20	14	1.85	8	0.80	3.96
			Pipestone Creek Site 2				
06/22/89	5	12.20 (0.37)	8.80 (0.58)	1.62 (0.07)	3.00 (0.00)	0.58 (0.04)	5.18 (0.24)
08/07/96	5	12.20 (2.42)	8.80 (1.02)	1.71 (0.14)	3.20 (1.24)	0.48 (0.17)	4.71 (0.14)
06/26/97	5	9.80 (1.77)	7.00 (1.45)	1.56 (0.30)	3.60 (1.12)	0.45 (0.11)	4.91 (0.29)
08/13/97	5	7.40 (1.78)	4.60 (1.08)	1.03 (0.14)	1.20 (0.58)	0.38 (0.19)	4.99 (0.23)
09/17/97	5	6.00 (1.22)	3.40 (0.51)	0.80 (0.16)	0.60 (0.24)	0.26 (0.19)	4.31 (0.67)
07/13/98	5	3.20 (0.97)	3.20 (0.97)	0.78 (0.28)	1.20 (0.37)	0.80 (0.20)	4.71 (0.84)
08/19/98	5	4.60 (1.12)	3.40 (0.51)	0.92 (0.11)	0.80 (0.37)	0.34 (0.20)	4.33 (0.47)
09/13/98	5	5.40 (1.54)	4.20 (1.02)	1.09 (0.17)	1.60 (0.51)	0.57 (0.19)	3.86 (0.43)
07/13/99	5	14.00 (1.52)	7.60 (0.51)	0.75 (0.10)	5.00 (0.89)	0.14 (0.02)	5.79 (0.07)
08/16/99	5	17.80 (0.92)	11.60 (1.03)	1.23 (0.20)	7.20 (0.49)	0.22 (0.05)	5.53 (0.08)
09/15/99	5	17.40 (0.93)	13.00 (1.00)	1.77 (0.09)	6.80 (0.58)	0.46 (0.11)	5.03 (0.20)
06/21/00	5	17.40 (1.57)	11.20 (0.73)	0.87 (0.10)	5.80 (1.02)	0.13 (0.02)	5.78 (0.04)
07/21/00	5	16.60 (2.38)	12.40 (1.44)	1.62 (0.07)	5.40 (1.17)	0.53 (0.14)	5.06 (0.30)
08/22/00	5	14.60 (1.50)	10.80 (0.73)	1.55 (0.12)	4.40 (1.17)	0.18 (0.05)	5.66 (0.28)
07/19/01	5	14.00 (2.65)	8.40 (1.72)	1.15 (0.12)	4.00 (0.71)	0.41 (0.07)	5.20 (0.18)
08/23/01	5	12.80 (1.20)	8.60 (0.68)	1.43 (0.08)	5.20 (0.86)	0.31 (0.03)	5.76 (0.12)
09/12/01	5	11.40 (0.93)	8.40 (0.40)	1.67 (0.06)	4.00 (0.55)	0.36 (0.07)	5.44 (0.12)
7/10/02	5	15.80 (1.92)	10.20 (0.45)	1.36 (0.23)	6.60 (1.52)	0.33 (0.30)	5.20 (0.65)
8/13/02	5	13.40 (3.58)	9.80 (1.92)	1.53 (0.34)	4.40 (1.14)	0.25 (0.20)	5.10 (0.53)
9/18/02	5	15.40 (1.82)	10.20 (0.84)	1.64 (0.22)	4.40 (1.67)	0.48 (0.28)	5.09 (0.53)

Appendix A. continued.

Date	n	Taxa Richness	Family Richness	Family Diversity	EPT Richness	EPT Ratio	FBI
7/09/03	5	15.40 (3.78)	11.00 (3.08)	1.77 (0.18)	6.00 (2.00)	0.58 (0.26)	4.82 (0.23)
8/11/03	5	9.60 (2.70)	7.80 (2.05)	1.42 (0.15)	3.60 (1.14)	0.82 (0.25)	3.83 (0.47)
9/08/03	5	7.60 (1.95)	7.20 (1.48)	1.22 (0.43)	3.60 (1.82)	1.00 (0.00)	3.70 (0.56)
7/19/04	5	11.60 (3.85)	8.60 (2.07)	1.58 (0.27)	3.60 (1.52)	0.59 (0.05)	4.31 (0.25)
8/25/04	5	13.40 (0.89)	6.60 (1.14)	1.37 (0.13)	7.40 (1.34)	0.56 (0.14)	4.85 (0.29)
Pipestone Creek Site 2 – kick-net sample							
9/18/02	1	20	12	1.92	9	0.46	4.93
9/08/03	1	8	5	0.88	7	1.00	4.02